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(54) **IMPRINT APPARATUS AND METHOD OF MANUFACTURING ARTICLE**

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G03F 7/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B29C 59/026*** (2013.01); ***G03F 7/0002*** (2013.01)

(58) **Field of Classification Search**
CPC B29C 59/02; B29C 59/026
USPC 264/293; 425/385
See application file for complete search history.

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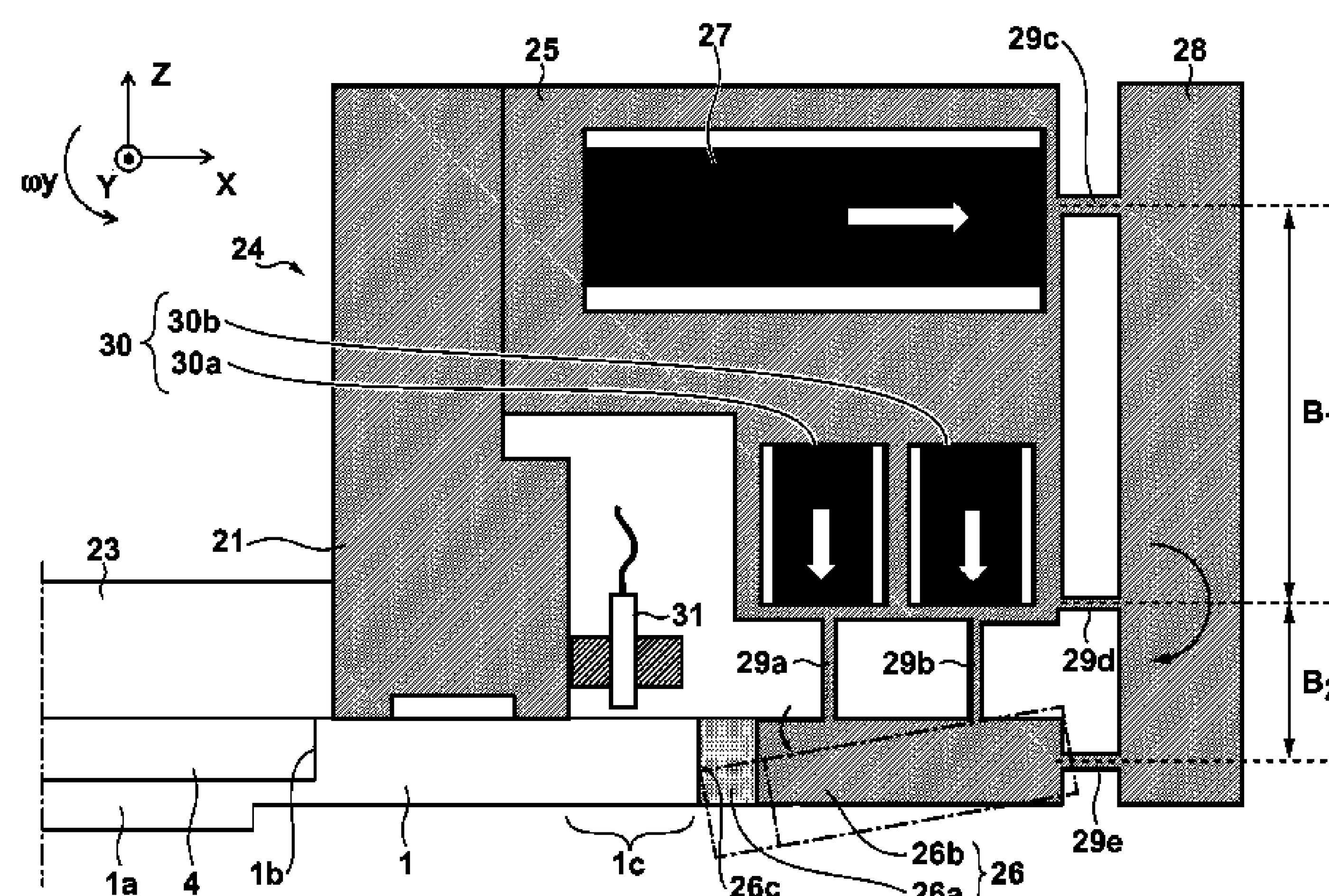
(57) **ABSTRACT**

The present invention provides an imprint apparatus which performs an imprint process in which a resin on a substrate is cured while a mold having a pattern formed thereon is pressed against the resin to transfer the pattern onto the substrate, the apparatus comprising a changing unit which includes a contact member having a contact surface that comes into contact with a side surface of the mold, and is configured to apply a force to the side surface of the mold through the contact member to change a shape of the pattern formed on the mold, and an adjusting unit configured to change at least one of an angle and a position of the contact member to adjust a contact state between the contact surface and the side surface of the mold.

27 Claims, 11 Drawing Sheets



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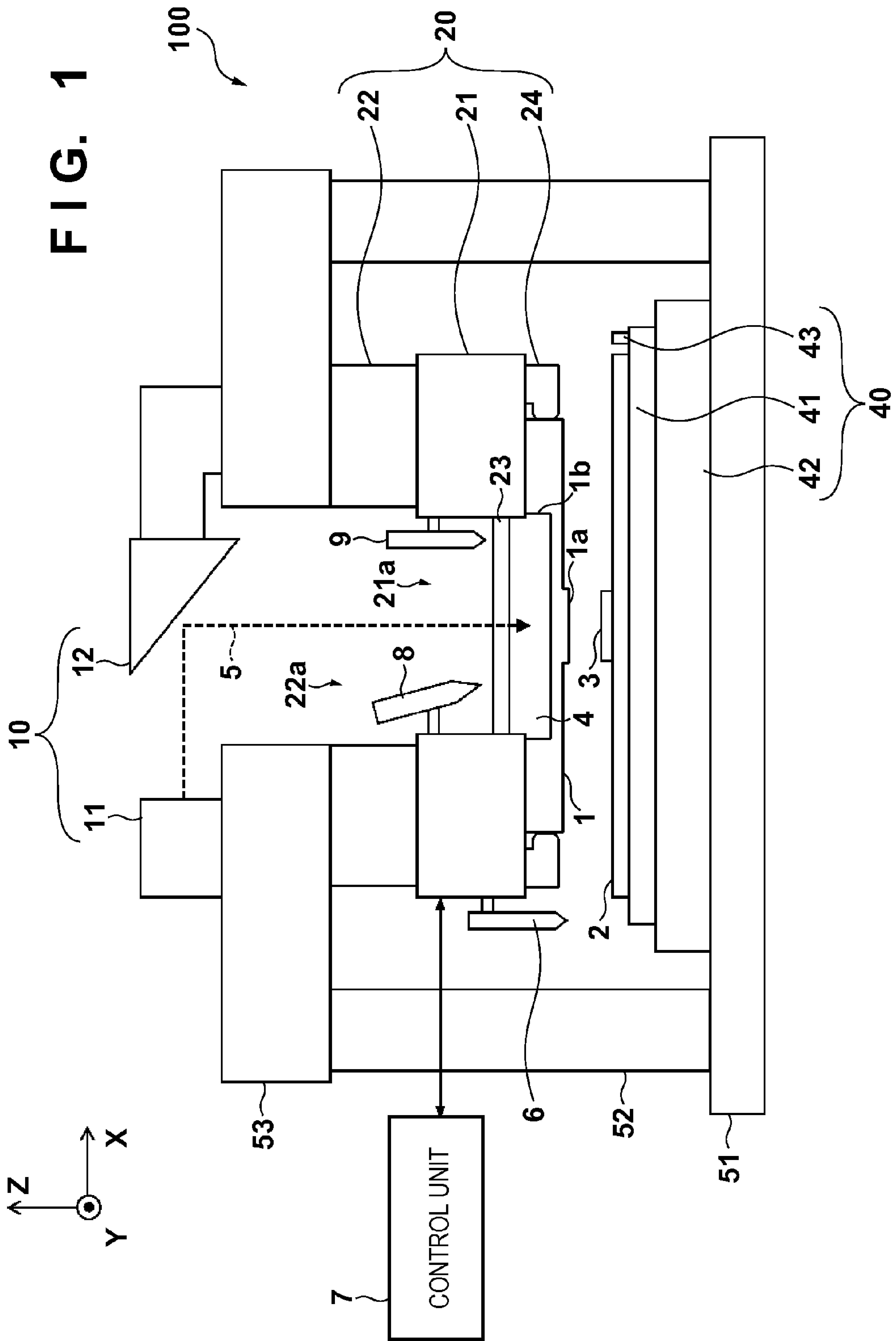
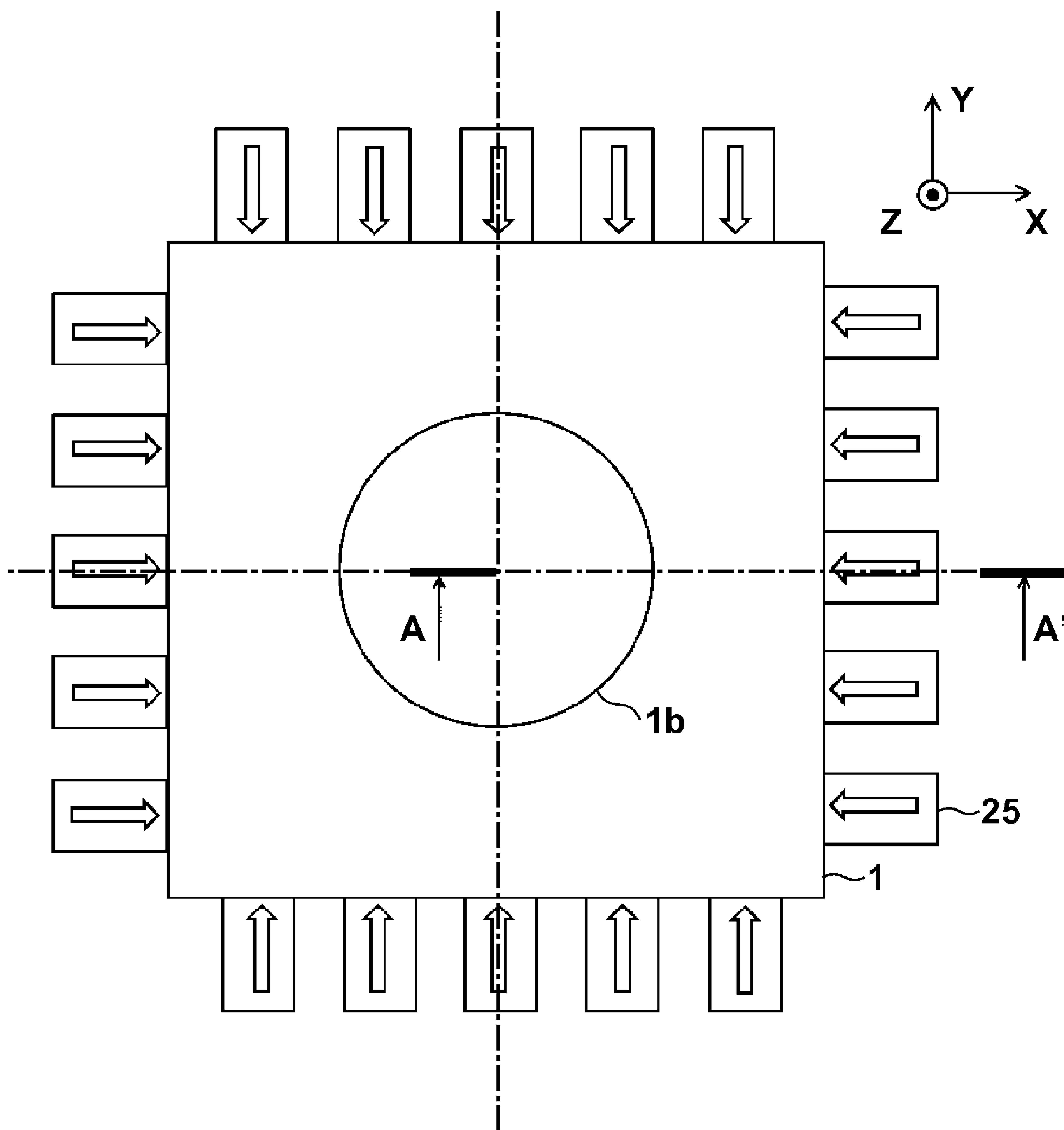


FIG. 1
100
20
22
21
24
10
12
11
9
23
1b
1a
21a
5
8
22a
3
4
1
43
41
42
40
2
6
53
52
51
Z
X
Y
7
CONTROL UNIT

FIG. 2



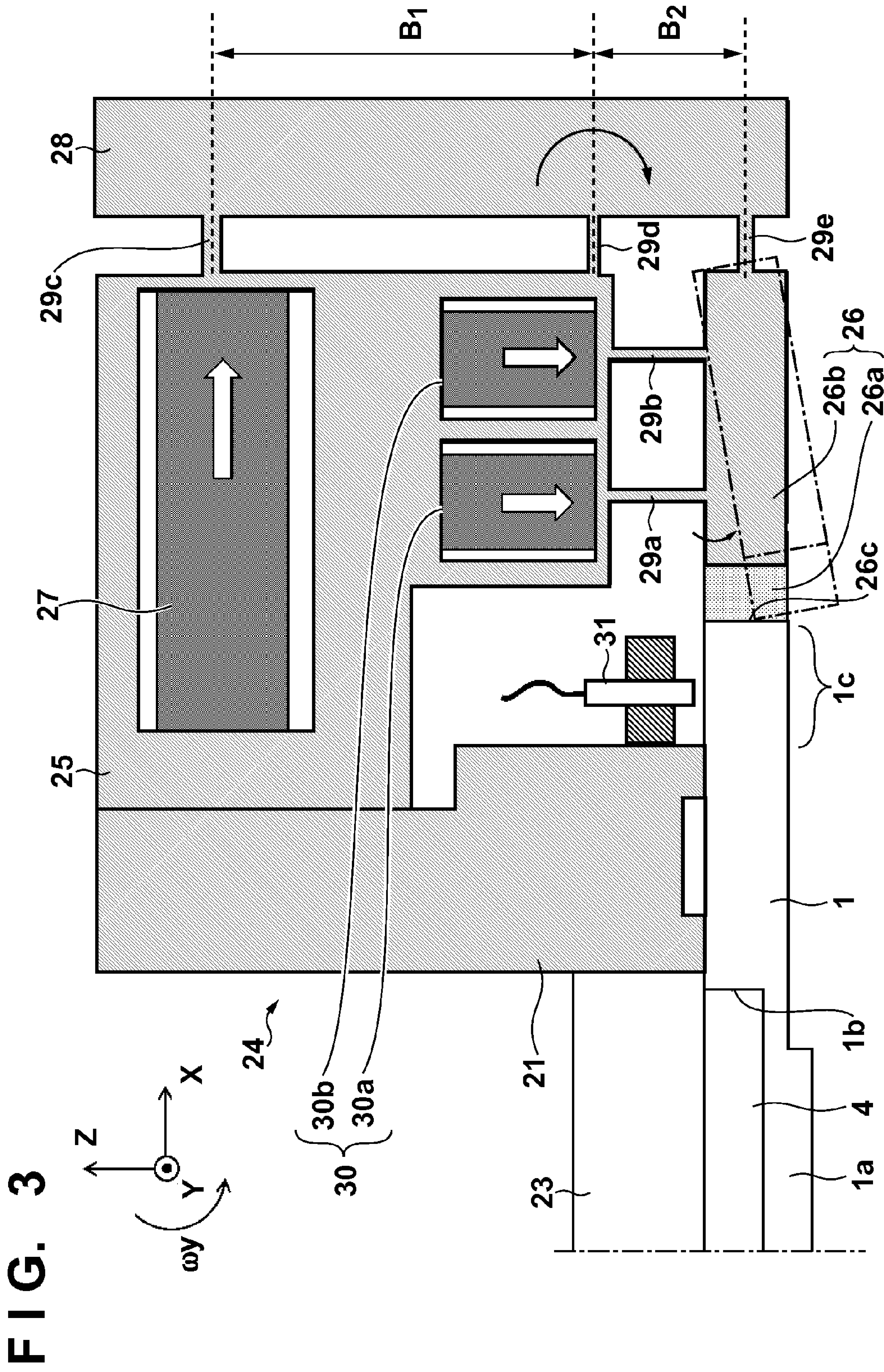


FIG. 3

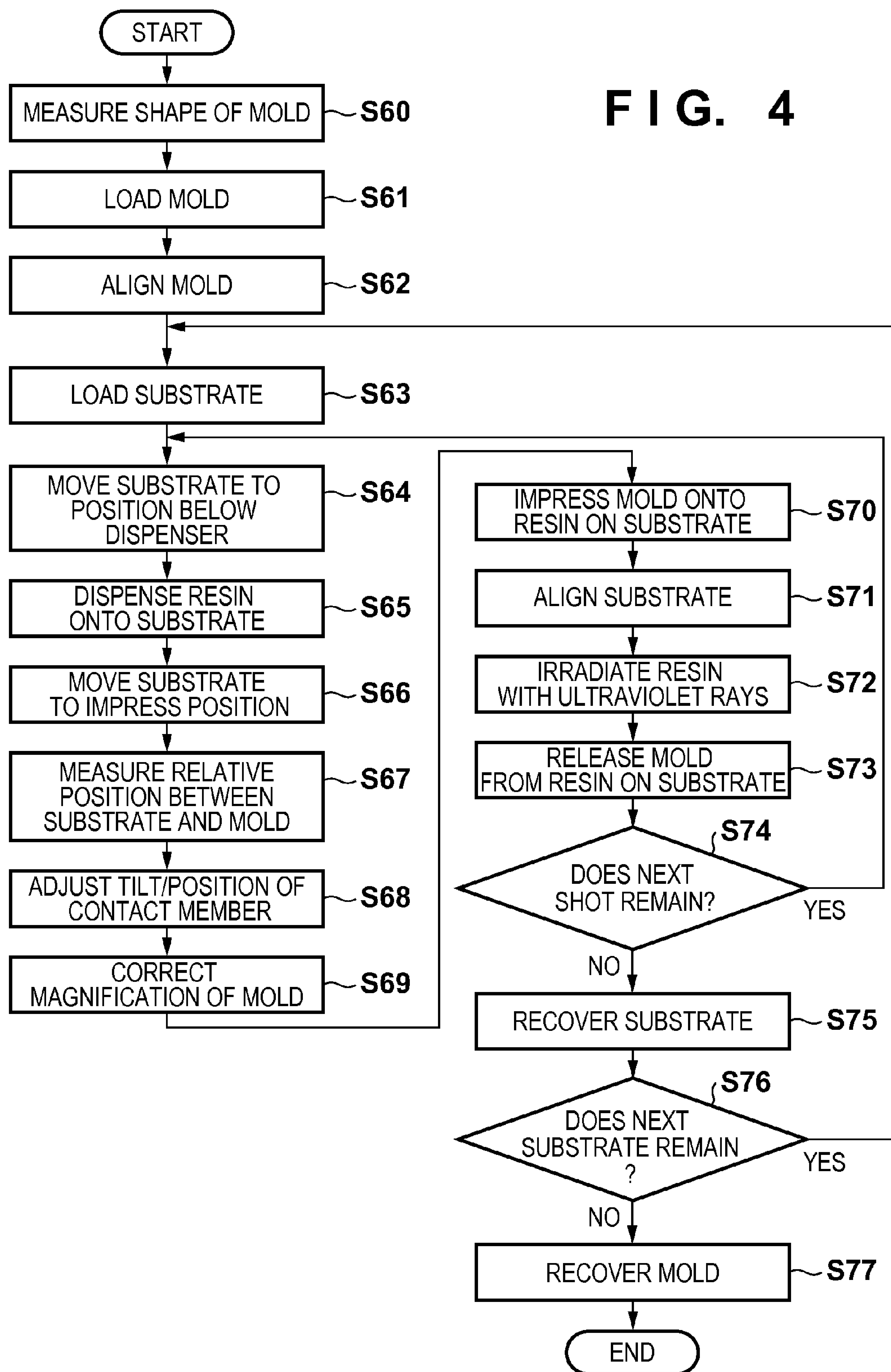


FIG. 4

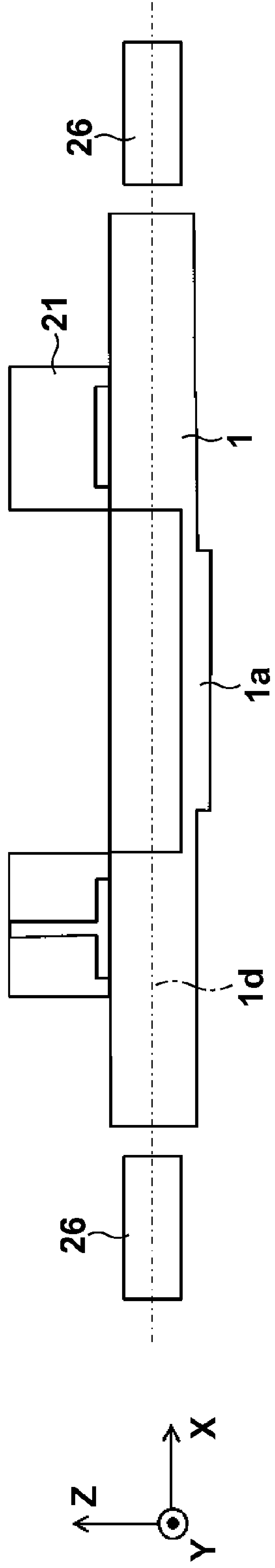


FIG. 5A

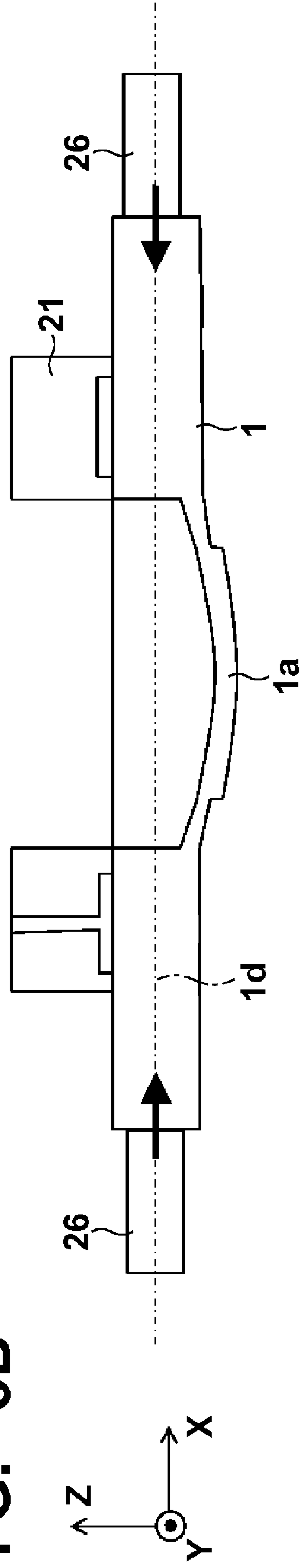


FIG. 5B

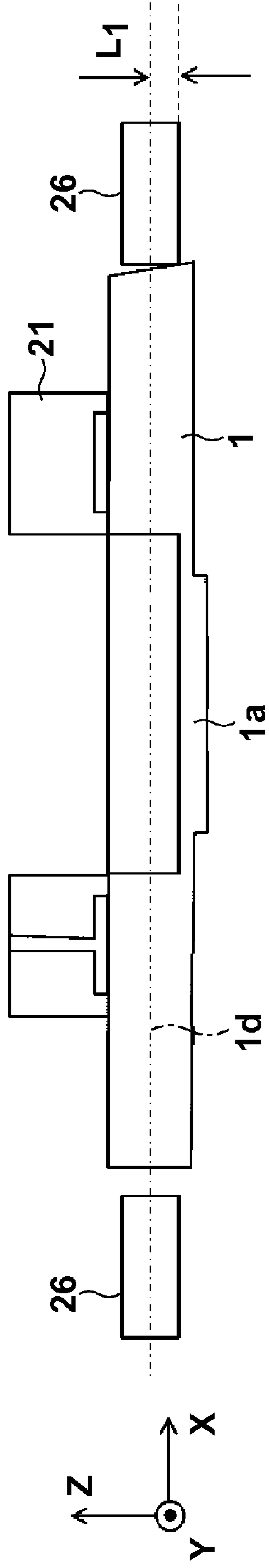


FIG. 6A

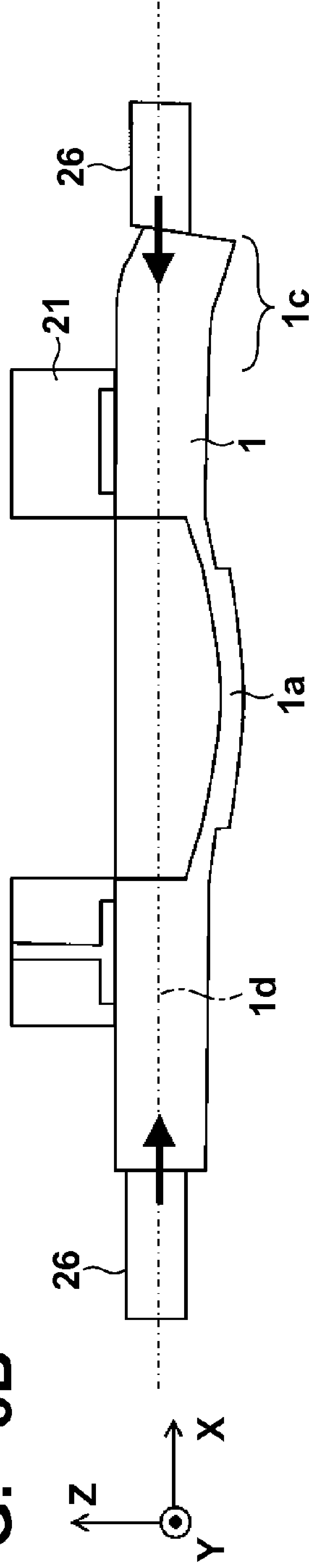


FIG. 6B

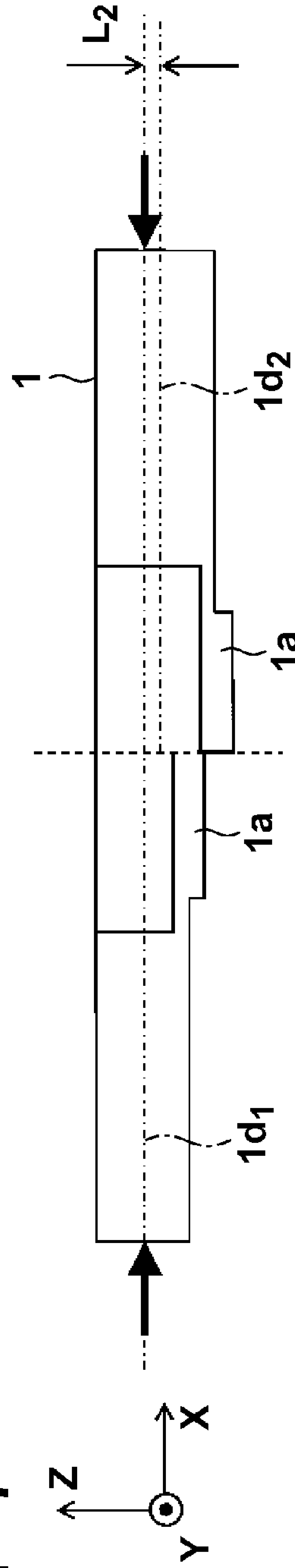
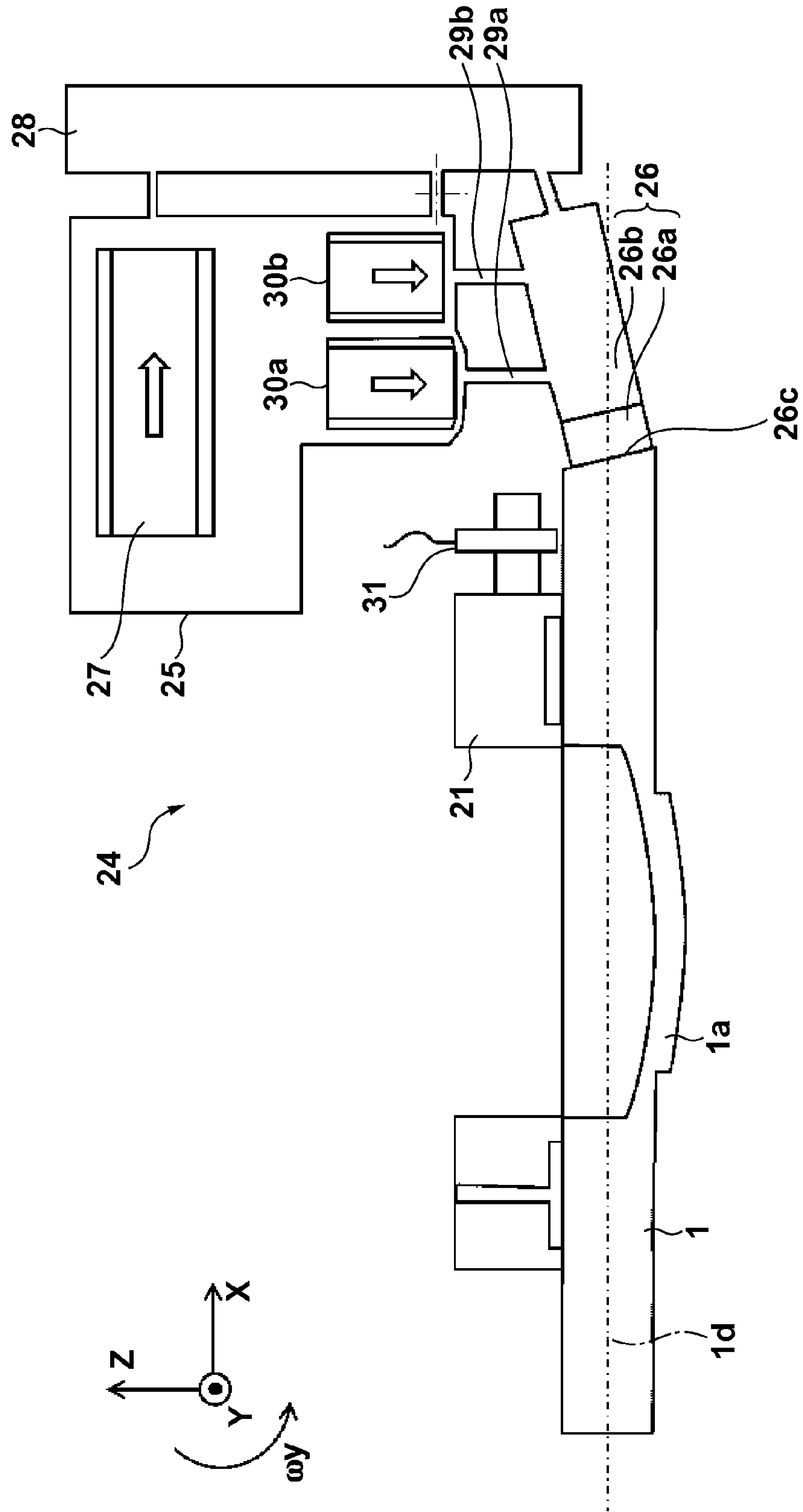


FIG. 7

FIG. 8



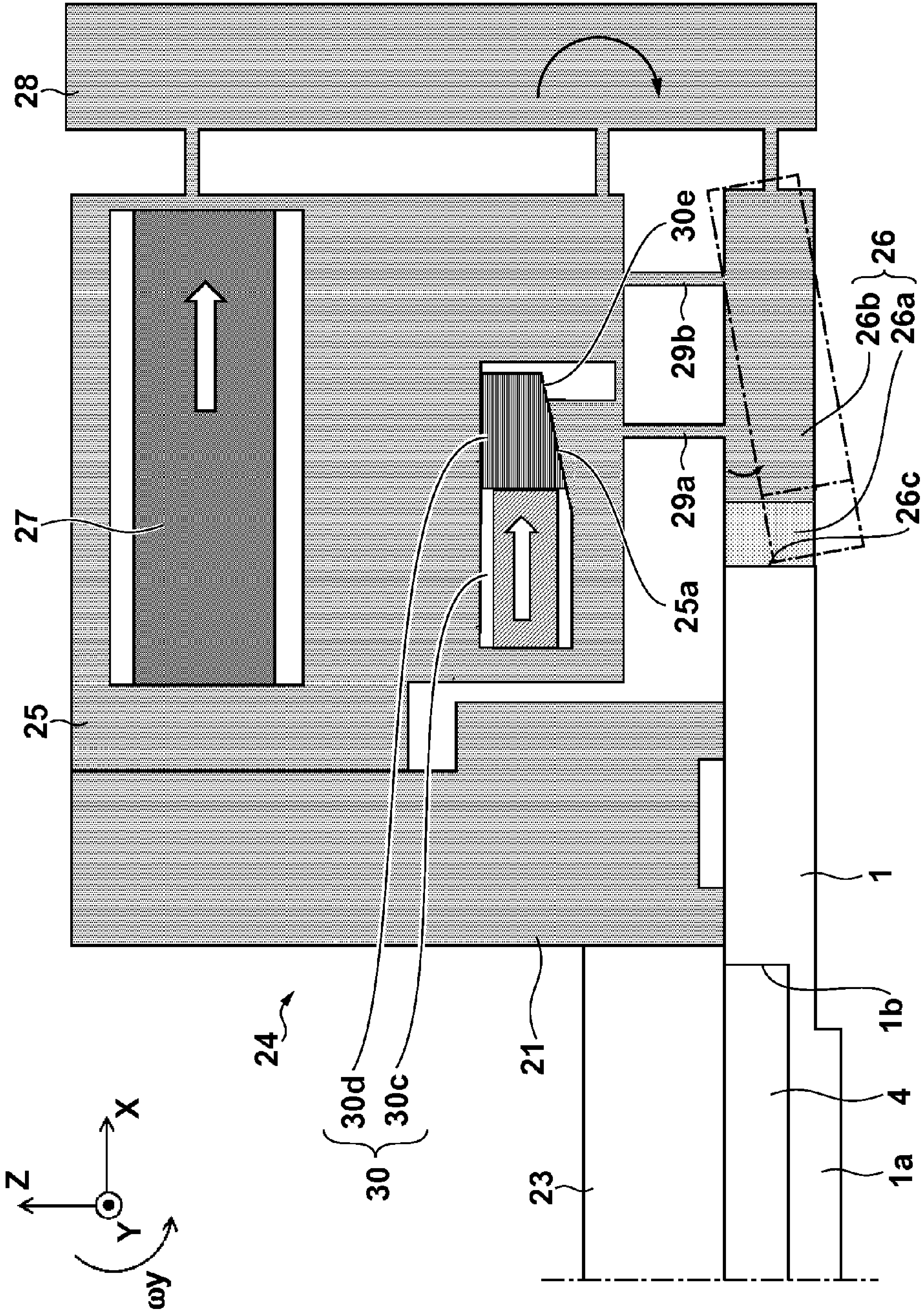


FIG. 9
28
30e
26
26b
26a
29b
29a
27
26c
25a
25
1
1b
24
21
4
30d
30c
30
23
1a
X
Z
Y
ωy

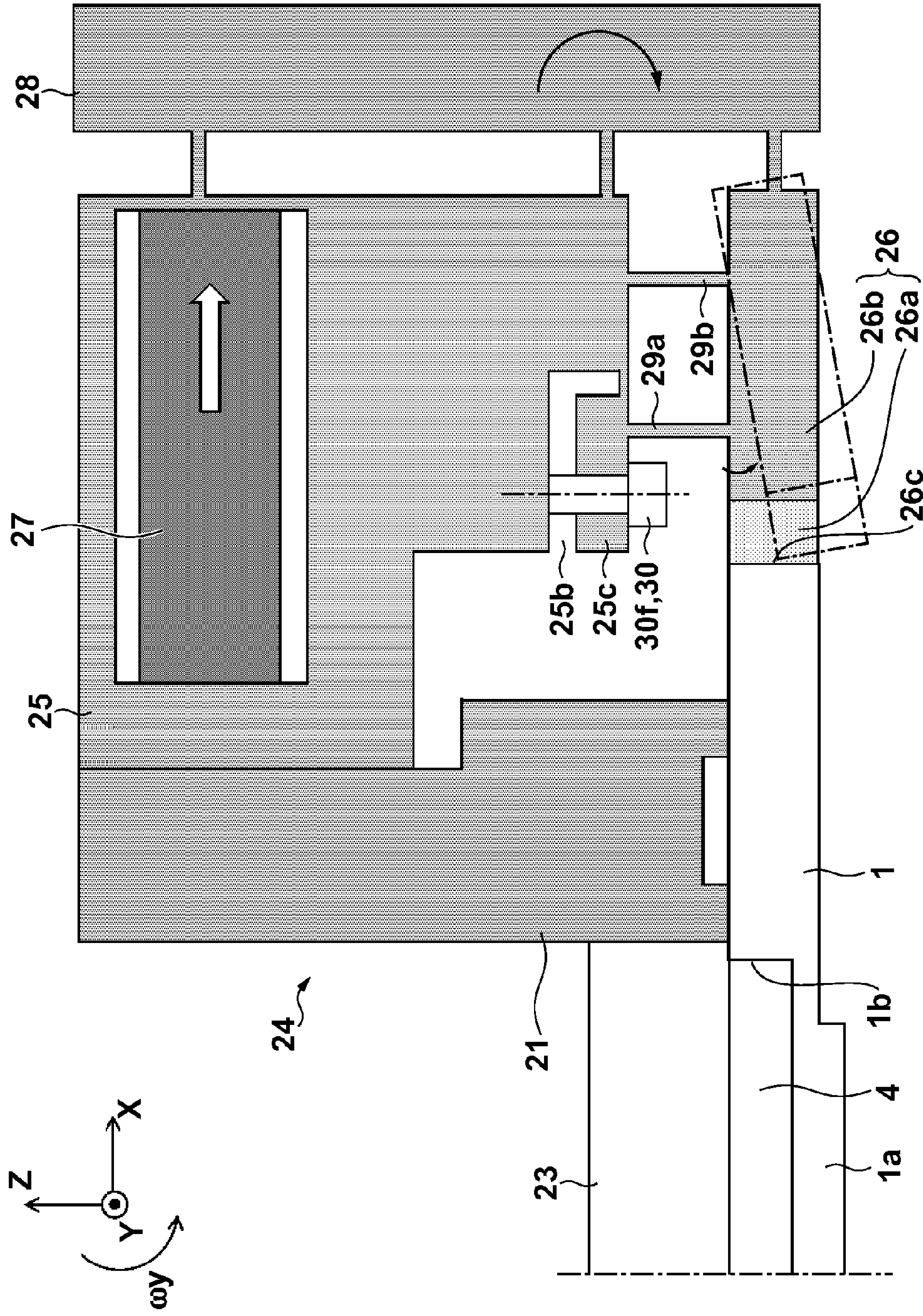
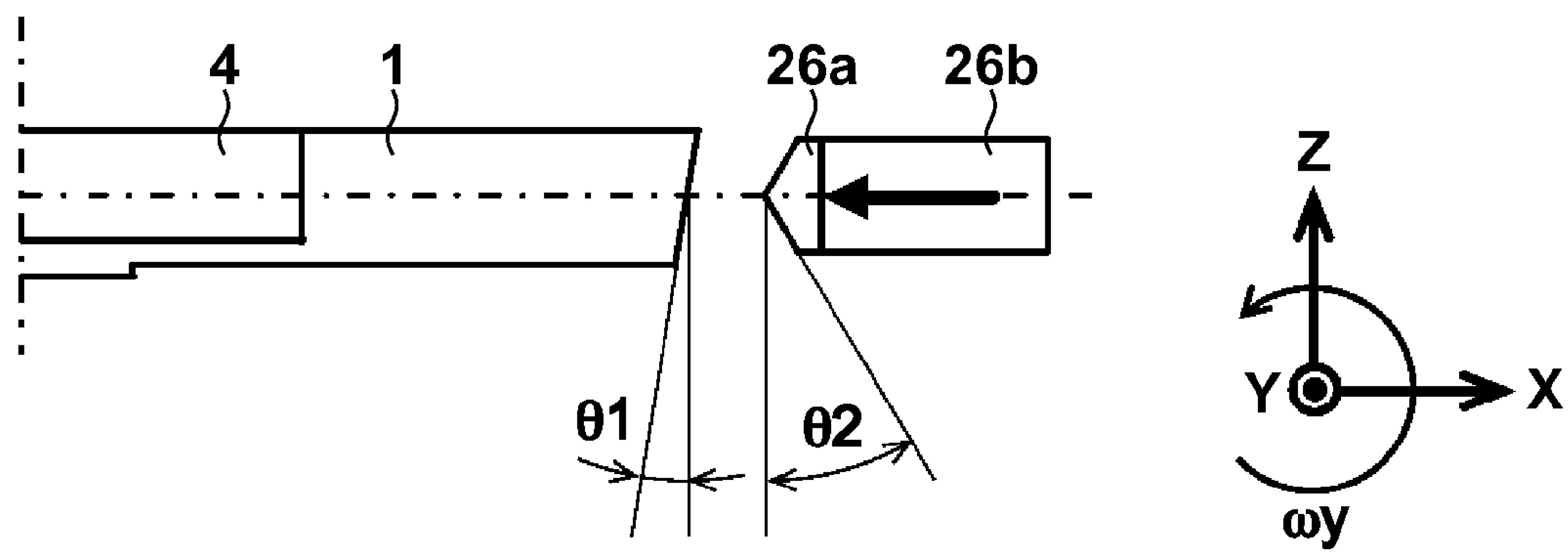


FIG. 10

FIG. 11

F I G. 12



IMPRINT APPARATUS AND METHOD OF MANUFACTURING ARTICLE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an imprint apparatus and a method of manufacturing an article.

Description of the Related Art

The imprint technique is attracting a great deal of attention as one of nano-lithography techniques for volume production of, for example, magnetic storage media and semiconductor devices. In the imprint technique, a mold having a fine pattern formed on it is pressed against a resin supplied onto a substrate, and the resin is cured in this state. By separating the mold from the cured resin, the pattern of the mold can be transferred onto the substrate.

In the imprint technique for manufacturing, for example, a semiconductor device, it is a common practice to use a plurality of molds to form a plurality of patterns on top of each other on a substrate. Hence, in an imprint apparatus which uses this technique, it is important to overlay the pattern of a mold on that of a substrate with high accuracy, so magnification correction in which the size of a pattern formed on a mold is corrected by pressing a plurality of portions on the side surface of the mold is performed. However, since the plurality of portions on the side surface of the mold have different shapes, a force may act in a direction, different from that in which the mold is pressed, when all portions are pressed in the same manner. If such a force acts, distortion may occur in the pattern of the mold, thus making it difficult to overlay the pattern of the mold on that of the substrate with high accuracy. To prevent this problem, Japanese Patent Laid-Open No. 2010-80714 describes a method of providing a plurality of holding units which hold a plurality of portions in the outer peripheral region of the mold, and independently driving the respective holding units in a direction (Z-direction) perpendicular to the substrate surface to correct the shape of the mold in accordance with that of the substrate.

An imprint apparatus described in Japanese Patent Laid-Open No. 2010-80714 uses a plurality of holding units to hold a mold in a plurality of portions of the outer peripheral region of the mold, and independently drives the respective holding units in the Z-direction to improve the overlay accuracy. Unfortunately, in such an imprint apparatus, the respective holding portions drive the respective portions of the mold in different amounts in the Z-direction (a direction perpendicular to the substrate surface), so the mold has a complicatedly distorted shape. That is, correcting the shape of the mold in accordance with that of the substrate improves the overlay accuracy, but leads to insufficient magnification correction of the pattern formed on the mold. Therefore, to overlay the pattern of the mold on that of the substrate with high accuracy, it is necessary to perform magnification correction while efficiently suppressing distortion generated by each holding unit. Further, since magnification correction must be done with high accuracy by increasing the number of portions where forces are applied to the mold, it is necessary to simplify a mechanism which performs magnification correction.

SUMMARY OF THE INVENTION

The present invention provides a technique advantageous in terms of accurately transferring the pattern of a mold onto a substrate in an imprint apparatus.

According to one aspect of the present invention, there is provided an imprint apparatus which performs an imprint process in which a resin on a substrate is cured while a mold having a pattern formed thereon is pressed against the resin to transfer the pattern onto the substrate, the apparatus comprising: a changing unit which includes a contact member having a contact surface that comes into contact with a side surface of the mold, and is configured to apply a force to the side surface of the mold through the contact member to change a shape of the pattern formed on the mold; and an adjusting unit configured to change at least one of an angle and a position of the contact member to adjust a contact state between the contact surface and the side surface of the mold.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing the configuration of an imprint apparatus according to the first embodiment;

FIG. **2** is a plan view of a mold as viewed from the side of irradiation with ultraviolet rays in the first embodiment;

FIG. **3** is a sectional view showing a cross-section of a changing unit in the first embodiment;

FIG. **4** is a flowchart showing an operation sequence in an imprint process according to the first embodiment;

FIGS. **5**A and **5**B are sectional views showing cross-sections of an ideal mold;

FIGS. **6**A and **6**B are sectional views showing cross-sections of the mold in the first embodiment;

FIG. **7** is a sectional view showing a cross-section of the mold in the first embodiment;

FIG. **8** is a sectional view showing a cross-section of the changing unit in the first embodiment;

FIG. **9** is a sectional view showing a cross-section of a changing unit in the second embodiment;

FIG. **10** is a sectional view showing a cross-section of a changing unit in the third embodiment;

FIG. **11** is a sectional view showing a cross-section of a changing unit in the fourth embodiment; and

FIG. **12** is a view showing a modification to the first embodiment.

DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the present invention will be described below with reference to the accompanying drawings. Note that the same reference numerals denote the same members throughout the drawings, and a repetitive description thereof will not be given.

First Embodiment

An imprint apparatus **100** according to the first embodiment of the present invention will be described with reference to FIG. **1**. The imprint apparatus performs an imprint process which is used to manufacture, for example, a semiconductor device, and in which a resin on a substrate is cured while a mold having a pattern formed on it is pressed against the resin, and the mold is separated from the cured resin to transfer the pattern onto the substrate. The imprint apparatus **100** according to the first embodiment includes a light irradiation unit **10** which irradiates a resin **3** on a substrate **2** with ultraviolet rays **5**, a mold holding unit **20** which holds a mold **1**, a substrate stage **40** which holds the substrate **2**, and a dispenser **6** which dispenses the resin **3**

onto the substrate **2**. The mold holding unit **20** is fixed to a bridge plate **53** supported by a base plate **51** through a support column **52**, and the substrate stage **40** is fixed to the base plate **51**. The imprint apparatus **100** also includes a control unit **7** which systematically controls an imprint process. Note that the imprint apparatus **100** according to the first embodiment employs the photo-curing method of curing a resin by irradiating it with ultraviolet rays. Also, in the following drawings, orthogonal directions on the substrate surface are defined as the X- and Y-directions, and a direction perpendicular to the substrate surface is defined as the Z-direction.

The mold **1** is generally made of a material capable of transmitting ultraviolet rays, such as quartz, and an unevenness pattern **1***a* to be transferred onto the substrate **2** is partially formed in its surface on the side of the substrate **2**. A cylindrical cavity (concave portion) **1***b* is formed in a surface, which holds the mold **1**, so as to reduce the thickness of the portion having the pattern **1***a* formed in it. The cavity **1***b* serves as an almost airtightly sealed space **4** by a light-transmissive member **23** disposed in an aperture region **21***a* in a mold chuck **21** (to be described later), and the pressure in the space **4** is controlled by a pressure adjustment apparatus (not shown). In, for example, pressing the mold **1** against the resin **3** on the substrate **2**, the pressure in the space **4** is set higher than the external pressure of the space **4**. At this time, the pattern **1***a* of the mold **1** deforms into a convex shape bulged toward the substrate **2**, so the pattern **1***a* can be brought into contact with the resin **3** from its central portion. This prevents the gas (air) from being entrapped in the gap between the pattern **1***a* and the resin **3**, thus making it possible to fill the unevenness portions of the pattern **1***a* with the resin **3** throughout its length and breadth so as to prevent loss of the pattern transferred onto the substrate **2**. Note that the depth of the cavity **1***b* is appropriately set in accordance with the size and material of the mold **1**.

A single-crystal silicon substrate or an SOI (Silicon On Insulator) substrate, for example, is used as the substrate **2**. An ultraviolet-curing resin (to be referred to as the resin **3** hereinafter) is dispensed onto the upper surface (the surface to be processed) of the substrate **2** by the dispenser **6** (to be described later), and the mold **1** is pressed against the resin **3** dispensed on the substrate **2**. By irradiating the resin **3** with ultraviolet rays while the mold **1** is pressed against the resin **3**, the resin **3** cures. The mold **1** is separated from the cured resin **3**.

The light irradiation unit **10** includes a light source **11** and optical element **12**, and irradiates the resin **3** on the substrate **2** with the ultraviolet rays **5** through the mold **1** in an imprint process. The light source **11** emits the ultraviolet rays **5** to cure the resin **3** dispensed on the substrate **2**, and the optical element **12** is implemented by a mirror which bends the ultraviolet rays **5** emitted by the light source **11**. In the first embodiment, the mold **1** having the pattern **1***a* formed on it is brought into contact with the resin **3** on the substrate **2**, and the resin **3** on the substrate **2** is irradiated with the ultraviolet rays **5** from the light source **11** in this state to be cured. Although the imprint apparatus **100** according to the first embodiment is provided with the light irradiation unit **10** to employ the photo-curing method, it may be equipped with a heat source unit for curing a thermosetting resin, in place of the light irradiation unit **10**, when, for example, the heat-curing method is employed.

The mold holding unit **20** includes the mold chuck **21** which holds the mold **1** by, for example, a vacuum absorption force or an electrostatic force, and a mold driving unit **22** which drives the mold chuck **21** to move the mold **1**. Aperture regions **21***a* and **22***a* are formed at the central portions (on the inner sides) of the mold chuck **21** and mold driving unit **22**, respectively, so as to irradiate the resin **3** on the substrate **2** with the ultraviolet rays **5** emitted by the light source **11** of the light irradiation unit **10**. The light-transmissive member **23** which transmits ultraviolet rays is disposed in the aperture region **21***a* of the mold chuck **21**, and allows the cavity **1***b* in the mold **1** to serve as an almost airtightly sealed space. The mold holding unit **20** also includes a changing unit **24** which applies a force to the side surface of the mold **1** to change the shape of the pattern **1***a* formed on the mold **1**. The changing unit **24** applies a force to the side surface of the mold **1** to change the shape of the pattern **1***a*, thereby performing magnification correction in which the size of the pattern **1***a* formed on the mold **1** is corrected with respect to the pattern formed on the substrate **2** in advance.

The mold driving unit **22** includes, for example, an actuator such as a linear motor or an air cylinder, and moves the mold **1** in the Z-direction so as to press the mold **1** against the resin **3** on the substrate **2** or separate it from the resin **3**. Note that since the mold driving unit **22** controls the position of the mold **1** with high accuracy, it may be implemented by a plurality of driving systems including a coarse driving system and fine driving system. The mold driving unit **22** may also have, for example, a position adjustment function of adjusting the position of the mold **1** by driving it in orthogonal directions (X- and Y-directions) on the substrate surface, and rotating it in the θ-direction, and a tilt function for correcting the tilt of the mold **1**. Although an operation of bringing the mold **1** and substrate **2** close to each other and separating them from each other is performed by the mold driving unit **22** in the imprint apparatus **100** according to the first embodiment, it may be performed by the substrate stage **40** (to be described later) or by both of them relative to each other.

The substrate stage **40** includes a substrate chuck **41** and stage driving unit **42**, and moves the substrate **2** in the X-Y plane to align the mold **1** and substrate **2** in pressing the mold **1** against the resin **3** on the substrate **2**. The substrate chuck **41** holds the substrate **2** by, for example, vacuum absorption, and includes a reference mark **43** used to align the mold **1**. The stage driving unit **42** mechanically holds the substrate chuck **41** to be movable in the X-Y plane. The stage driving unit **42** uses, for example, a linear motor, and may be implemented by a plurality of driving systems including a coarse driving system and fine driving system in the X- and Y-directions. The stage driving unit **42** may also have, for example, a position adjustment function of adjusting the position of the substrate **2** by driving it in orthogonal directions (X- and Y-directions) on the substrate surface, and rotating it in the θ-direction, and a tilt function for correcting the tilt of the substrate **2**.

The dispenser **6** dispenses the resin **3** (uncured resin) onto the substrate **2**. As described above, the resin **3** used in the first embodiment is a photo-curing resin (imprint material) having the property that it cures upon irradiation with the ultraviolet rays **5**, and is appropriately selected in accordance with various conditions in the process of manufacturing a semiconductor device. Also, the amount of the resin **3** discharged from discharge nozzles of the dispenser **6** is appropriately determined in accordance with, for example, the thickness or density of an unevenness pattern formed upon the resin **3** on the substrate **2**.

The control unit **7** controls, for example, operations and adjustment in each constituent element of the imprint appa-

ratus **100**. The control unit **7** is implemented by, for example, a computer, and connected to each constituent element of the imprint apparatus **100**. The imprint apparatus **100** also includes an alignment measurement unit **8** which measures a position deviation between alignment marks on the mold **1** and substrate **2**, respectively, and a distance measurement unit **9** which measures the distance between the mold **1** and the substrate **2**. As wafer alignment, the alignment measurement unit **8** measures, for example, a position deviation, in the X- and Y-directions, between the alignment marks formed on the substrate **2** and mold **1**, respectively. The distance measurement unit **9** measures, for example, the distance by observing, using an image sensor, interfering light generated as light emitted toward the substrate **2** by a light source for measurement passes through the mold **1**, is reflected by the substrate **2**, and passes through the mold **1** again, thereby bringing about interference.

The changing unit **24** which applies a force to the side surface of the mold **1** to change the shape of the pattern **1***a* formed on the mold **1** will be described herein with reference to FIGS. **2** and **3**. FIG. **2** is a plan view of the mold **1** as viewed from the side of irradiation with the ultraviolet rays **5**. The mold **1** includes five changing units **24** on each side, that is, a total of 20 changing units **24**, and inward forces are applied to the changing units **24** from the side surface of the mold **1**, as indicated by arrows in the changing units **24** shown in FIG. **2**. With this arrangement, by providing a plurality of changing units **24** on each side of the mold **1**, magnification correction of the pattern **1***a* formed on the mold **1** with respect to the pattern formed on the substrate **2** in advance can be performed with high accuracy.

FIG. **3** is a sectional view showing a cross-section of the mold **1** and changing unit **24** corresponding to an interval A-A' shown in FIG. **2**. The changing unit **24** includes a base unit **25**, a contact member **26**, an actuator **27**, a lever **28**, and a plurality of members **29***a* to **29***e*. The base unit **25** is fixed to the mold holding unit **20** (mold chuck **21**) and includes the actuator **27**. Upon applying a force to the side surface of the mold **1**, the base unit **25** receives a reaction force to that force. The contact member **26** is formed by a resin member **26***a* and block member **26***b*. The resin member **26***a* has a contact surface **26***c* which comes into contact with the side surface of the mold **1**, and uses a resin with excellent elasticity, such as polytetrafluoroethylene (PTFE) or polyoxymethylene (POM), to reduce stress concentration on the mold **1** so as to prevent a fracture of the mold **1**. The block member **26***b* is formed integrally with the resin member **26***a*, and supported by the base unit **25** through the members **29***a* and **29***b*. The members **29***a* and **29***b* are implemented by, for example, leaf springs, and form a link mechanism which allows the contact member **26** to move in the direction (first direction) in which the contact member **26** presses the mold **1**. The actuator **27** is disposed in the base unit **25**, and the contact member **26** applies a force to the member **29***c* in a direction (X-direction) opposite to that (first direction) in which the contact member **26** presses the mold **1** to displace the member **29***c* in the X-direction, as indicated by an arrow in FIG. **3**. The lever **28** is supported by the base unit **25** through the members **29***c*, **29***d*, and **29***e*. The members **29***c*, **29***d*, and **29***e* can be implemented by, for example, leaf springs, like the members **29***a* and **29***b*.

When a force is generated in the X-direction by the actuator **27**, it is transmitted to the upper portion of the lever **28** through the member **29***c*, so the upper portion of the lever **28** is displaced in the X-direction. At this time, the lever **28** rotates using the member **29***d* as a fulcrum, and the rotated lever **28** converts a displacement of the upper portion of the lever **28** in the X-direction into that of the lower portion of the lever **28** in the −X-direction. A displacement of the lower portion of the lever **28** in the −X-direction is transmitted to the contact member **26** through the member **29***e* to move the contact member **26** in the direction (−X-direction) in which the contact member **26** presses the mold **1**. The ratio (driving magnification) between the displacements of the upper and lower portions of the lever **28** is determined by a distance B_1 between the members **29***c* and **29***d*, and a distance B_2 between the members **29***d* and **29***e*, and is B_2/B_1. The block member **26***b* of the contact member **26** is supported by the base unit **25** through the members **29***a* and **29***b* which form the link mechanism, and allows the mold **1** to move in the direction (−X-direction) in which the mold **1** is pressed, while suppressing displacements of the mold **1** in directions other than the −X-direction. Also, the resin member **26***a* of the contact member **26** brings the contact surface **26***c* into contact with the side surface of the mold **1** to apply a force to the side surface of the mold **1**. The force can be monitored by, for example, a distortion sensor, a force sensor, or a displacement sensor (neither is shown). Although a piezoelectric actuator is used as the actuator **27** according to the first embodiment in consideration of the generated force, resolution, and response, an air cylinder or an electromagnetic motor, for example, may also be used.

The changing units **24** configured as mentioned above perform magnification correction in which the size of the pattern **1***a* formed on the mold **1** is corrected by pressing a plurality of portions on the side surface of the mold **1**, as shown in FIG. **2**. However, since the plurality of portions on the side surface of the mold **1** have different shapes, a force may act in a direction, different from that in which the mold **1** is pressed, when all portions are pressed in the same manner, without adjusting either the angle or position of the contact member **26**. If such a force acts, stress concentration may occur locally in the pattern **1***a* of the mold **1** to generate distortion, thus making it difficult to overlay the pattern **1***a* of the mold **1** on that of the substrate with high accuracy. To prevent this problem, the changing unit **24** according to the first embodiment is provided with an adjusting unit **30** which adjusts the angle and position of the contact member **26**. The adjusting unit **30** is formed by actuators **30***a* and **30***b* which apply displacements in the Z-direction to the members **29***a* and **29***b*, respectively. The actuators **30***a* and **30***b* are arranged in the base unit **25**, and drive the members **29***a* and **29***b*, respectively, in a direction (second direction (−Z-direction)) different from that (first direction) in which the contact member **26** presses the mold **1**. This makes it possible to change the angle in the ωy-direction and the position in the Z-direction for the contact member **26**. If, for example, only the member **29***a* is displaced in the Z-direction by the actuator **30***a*, the angle of the contact member **26** can be changed, as indicated by an alternate long and two short dashed line in FIG. **3**. However, if the members **29***a* and **29***b* are displaced in the same amount in the Z-direction by the actuators **30***a* and **30***b*, respectively, the position of the contact member **26** in the Z-direction can be changed without changing the angle of the contact member **26**. With this arrangement, the changing unit **24** according to the first embodiment can adjust at least one of the angle and position of the contact member **26**, and it can adjust the contact state between the contact surface **26***c* of the contact member **26** (resin member **26***a*) and the side surface of the mold **1**. That is, a force can be applied to the side surface of the mold **1** by adjusting the contact surface **26***c* so that the contact surface **26***c* is set parallel to the side surface of the mold **1**, and the center of the contact surface **26***c* is set at the neutral

position of rigidity of the mold **1** in the Z-direction. The neutral position of rigidity (to be referred to as the neutral position **1***d* hereinafter) means herein the position at which the moment of rotation that acts on the mold **1** minimizes as a force is applied to the side surface of the mold **1**.

The driving amounts required for the actuators **30***a* and **30***b* to adjust the contact member **26** can be determined by measuring, in advance, the shape information of the mold **1** used, using, for example, a three-dimensional measurement device, before the mold **1** is loaded into the imprint apparatus **100**. The shape information of the mold **1** can include at least one of, for example, the thickness of the mold **1**, and the tilt of the side surface of the mold **1**. The driving amounts required for the actuators **30***a* and **30***b* to adjust the contact member **26** can also be determined based on the deformation amount of an outer peripheral region **1***c* of the mold **1**. In this case, a measurement unit **31** which measures the deformation amount in which the outer peripheral region **1***c* of the mold **1** deforms in a direction (−Z-direction) different from that in which the mold **1** is pressed is provided in the imprint apparatus **100**. A force generated by the actuator **27** is applied to the side wall of the mold **1** through the contact member **26**, and the actuators **30***a* and **30***b* are driven to reduce the deformation amount of the outer peripheral region **1***c* of the mold **1**, which is measured by the measurement unit **31**. At this time, by finely adjusting the driving amounts of the actuators **30***a* and **30***b*, the influence of, for example, an assembly error of the apparatus can also be suppressed. The outer peripheral region **1***c* of the mold **1** means herein a region that falls outside the portion where the mold **1** is held by the mold holding unit **20** (mold chuck **21**).

The driving amounts required for the actuators **30***a* and **30***b* to adjust the contact member **26** can also be determined based on a position deviation between the alignment marks formed on the mold **1** and substrate **2**, respectively. In this case, the aperture region **21***a* in the mold chuck **21** is provided with the alignment measurement unit **8** which measures a position deviation, in the X- and Y-directions, between the alignment marks formed on the mold **1** and substrate **2**, respectively, as shown in FIG. **1**. The actuators **30***a* and **30***b* are driven to reduce the position deviation measured by the alignment measurement unit **8**.

An imprint process in which the pattern **1***a* of the mold **1** is transferred onto the substrate **2** in the imprint apparatus **100** according to the first embodiment, configured as mentioned above, will be described with reference to FIG. **4**. FIG. **4** is a flowchart showing an operation sequence in an imprint process in which the unevenness pattern **1***a* formed on the mold **1** is transferred onto a plurality of substrates **2**.

In step S**60**, before the mold **1** is loaded into the imprint apparatus **100**, the shape of the mold **1** is measured in advance by, for example, a three-dimensional measurement device to obtain the shape information of the mold **1**. In step S**61**, the control unit **7** controls a mold conveyance mechanism (not shown) to convey the mold **1** to a position below the mold chuck **21**, and controls the mold chuck **21** to hold the mold **1**. With this operation, the mold **1** is loaded into the imprint apparatus **100**. In step S**62**, the control unit **7** uses the alignment measurement unit **8** to measure a position deviation, in the X-, Y-, and θ-directions, between the reference mark **43** and the alignment mark formed on the mold **1**. The control unit **7** controls the mold driving unit **22** to align the reference mark **43** and the alignment mark formed on the mold **1**, based on the measurement result obtained by the alignment measurement unit **8**. In step S**63**, the control unit **7** controls a substrate conveyance mechanism (not shown) to convey the substrate **2** onto the substrate chuck **41**, and controls the substrate chuck **41** to hold the substrate **2**. With this operation, the substrate **2** is loaded into the imprint apparatus **100**. In step S**64**, the control unit **7** controls the stage driving unit **42** to set a shot region (a region to undergo an imprint process) on the substrate **2** at a position below the dispenser **6** to move the substrate **2**. In step S**65**, the control unit **7** controls the dispenser **6** to dispense a resin **3** (uncured resin) to the shot region on the substrate **2**. In step S**66**, the control unit **7** controls the stage driving unit **42** to set the shot region on the substrate **2**, dispensed with the resin **3**, at a position below the pattern **1***a* of the mold **1** to move the substrate **2**. In step S**67**, the control unit **7** controls the alignment measurement unit **8** to measure a position deviation between the alignment marks formed on the substrate **2** and mold **1**, respectively, during or after the movement of the substrate **2**. Based on the measurement result obtained by the alignment measurement unit **8**, the control unit **7** calculates the driving amount of the actuator **27**, which is required for the changing unit **24** (contact member **26**) to press the mold **1** from its side surface, in magnification correction of the pattern **1***a* formed on the mold **1**. In step S**68**, the control unit **7** controls the actuators **30***a* and **30***b* to adjust the angle and position of the contact member **26**. The control unit **7** calculates the driving amounts of the actuators **30***a* and **30***b* based on the shape information of the mold **1** measured in advance in step S**60**. In step S**69**, the control unit **7** drives the actuator **27** based on the driving amount of the actuator **27**, which is calculated in step S**67**, to apply a force to the side surface of the mold **1** through the contact member **26**. With this operation, the shape of the mold **1** is changed to perform magnification correction of the pattern **1***a* of the mold **1**. Note that the processes in steps S**68** and S**69** may also be executed in or after pressing the mold **1** against (impressing it onto) the resin **3** on the substrate **2** in step S**70** (to be described later). Also, the process in step S**68** may be executed in or after magnification correction of the pattern **1***a* of the mold **1** in step S**69**.

The shape of the mold **1** as the changing unit **24** applies a force to the side surface of the mold **1** will be described herein. FIGS. **5**A and **5**B are views showing the shapes of an ideal mold before and after the changing unit **24** applies a force to the side surface of the mold **1**. The ideal mold **1** is formed so that all portions on the side surface of the mold **1** are parallel to the Z-axis, and are uniform in the thickness of the outer peripheral region **1***c* of the mold **1**, as shown in FIG. **5**A. Using such an ideal mold **1**, the contact surface **26***c* of the contact member **26** is set parallel to the side surface of the mold **1**, and the center of the contact surface **26***c* is set at the neutral position **1***d* of the mold **1**, without adjusting the contact member **26**. When the changing units **24** apply forces to the side surface of the ideal mold **1**, the thin portion of the pattern **1***a* in the ideal mold **1** deforms into a convex shape bulged toward the substrate **2**, as shown in FIG. **5**B. However, an actual mold often has a side surface that is not parallel to the Z-direction, as shown in FIG. **6**A, or has a thickness that varies due, for example, to the differences between individual molds, as shown in FIG. **7**. Referring to FIG. **7**, the left side of a broken line shows the case wherein the mold **1** is fabricated with a thickness smaller than a design value, and the right side of the broken line shows the case wherein it is fabricated with a thickness larger than the design value.

In a mold **1** having a side surface that is not parallel to the Z-axis, as shown in FIG. **6**A, when a force is applied to its side surface, the contact member **26** comes into contact with the side surface of the mold **1** from a position spaced apart

from the neutral position **1**d by a distance L_1 in the −Z-direction. When a force is applied to the side surface of the mold **1** in such a contact state, the outer peripheral region **1**c of the mold **1** deforms in the −Z-direction or in a bilaterally asymmetric shape, as shown in FIG. **6**B. When the outer peripheral region **1**c of the mold **1** has deformed, distortion occurs in the pattern **1**a of the mold **1**, so the pattern **1**a of the mold **1** cannot be overlaid on that of the substrate **2** with high accuracy. Also, as shown in FIG. **7**, in a mold **1** with a thickness that varies due, for example, to the differences between individual molds, the portions on the left and right sides of the broken line have neutral positions **1**d_1 and **1**d_2 spaced apart from each other by a distance L_2. Therefore, when a force is applied to the side surface of the mold **1** without adjusting the contact member **26**, the mold **1** deforms in the same manner as in FIG. **6**B. To prevent this problem, in the imprint apparatus **100** according to the first embodiment, the changing unit **24** includes the actuators **30**a and **30**b, which adjust at least one of the angle ωy and the position, in the Z-direction, of the contact member **26**, as described above. This makes it possible to adjust the angle of the contact member **26** so that the contact surface **26**c of the contact member **26** becomes parallel to the side surface of the mold **1**, and, in turn, to adjust the center of the contact surface **26**c to the neutral position **1**d of the mold **1**. That is, it is possible to adjust the contact state between the side surface of the mold **1** and the contact surface **26**c of the contact member **26**.

A method of adjusting the angle ωy and the position, in the Z-direction, of the contact member **26** with respect to a mold **1** having a shape as shown in FIG. **6**A will be described with reference to FIG. **8**. The shape of the mold **1** is measured in advance using, for example, a three-dimensional measurement device, as described in step S**60**, and the contact member **26** is adjusted based on the measurement result. The side surface of the mold **1** used in FIG. **8** has an inclined shape instead of a shape parallel to the Z-axis. First, the angle ωy of the contact member **26** is adjusted so that the contact surface **26**c of the contact member **26** becomes parallel to the inclined side surface of the mold **1**. More specifically, only the actuator **30**a is activated while the actuator **30**b is kept stopped. With this operation, only the member **29**a is displaced in the −Z-direction without displacing the member **29**b, and the portion on the side of the contact surface **26**c of the contact member **26** descends in the −Z-direction, so the angle ωy of the contact member **26** is adjusted so that the contact surface **26**c of the contact member **26** becomes parallel to the side surface of the mold **1**. The position of the contact member **26** in the Z-direction is adjusted so that the center of the contact surface **26**c is set at the neutral position **1**d of the mold **1**. More specifically, both the actuators **30**a and **30**b are driven in the same amount. With this operation, the position of the contact member **26** in the Z-direction is adjusted so that the center of the contact surface **26**c is set at the neutral position **1**d of the mold **1**, without changing the angle ωy of the contact member **26**. After the angle ωy and the position, in the Z-direction, of the contact member **26** are adjusted, the actuator **27** is activated to move through the lever **28** the contact member **26** in the direction (−X-direction) in which the mold **1** is pressed. As described above, the contact member **26** is supported by the base unit **25** through the members **29**a and **29**b which form the link mechanism, and therefore can be moved in the direction (−X-direction), in which the mold **1** is pressed from its side surface, without changing the angle ωy and the position in the Z-direction. In this manner, stress concentration that may occur locally in the pattern **1**a of the mold **1** can be suppressed by adjusting the angle ωy and the position, in the Z-direction, of the contact member **26**. Although the angle of the contact member **26** in the ωy-direction is adjusted by adopting a configuration which applies a force to the mold **1** in the X-direction (−X-direction) using the changing unit **24** in FIG. **8**, the angle of the contact member **26** in the ωx-direction may be adjusted by adopting a configuration which applies a force to the mold **1** in the Y-direction (−Y-direction). Also, a distortion sensor, a force sensor, or a displacement sensor may be separately provided when the driving amounts of the actuators **27**, **30**a, and **30**b are controlled with high precision.

In step S**70**, the control unit **7** controls the mold driving unit **22** to press (imprint) the mold **1** against the resin **3** on the substrate **2** when the shape of the mold **1** has changed. In step S**71**, the control unit **7** controls the alignment measurement unit **8** to measure a position deviation between the alignment marks formed on the substrate **2** and mold **1**, respectively, that has occurred in step S**70**. The control unit **7** controls the substrate stage **40** to reduce the position deviation measured by the alignment measurement unit **8** to move the substrate **2**. In step S**72**, the control unit **7** controls the light irradiation unit **10** to irradiate the resin **3**, against which the mold **1** is pressed, with the ultraviolet rays **5** to cure the resin **3**. In step S**73**, the control unit **7** controls the mold driving unit **22** to separate (release) the mold **1** from the resin **3** on the substrate **2**. In step S**74**, the control unit **7** determines whether a shot region in which a pattern is to be formed next remains on the substrate **2**. If the next shot region remains, the process returns to step S**64**; otherwise, the process advances to step S**75**. In step S**75**, the control unit **7** controls the substrate conveyance mechanism (not shown) to recover the substrate **2** from the substrate chuck **41**. In step S**76**, the control unit **7** determines whether a substrate to undergo an imprint process next remains. If the next substrate remains, the process returns to step S**63**; otherwise, the process advances to step S**77**. In step S**77**, the control unit **7** controls the mold conveyance mechanism (not shown) to recover the mold **1** from the mold chuck **21**.

As described above, in the imprint apparatus **100** according to the first embodiment, the changing unit **24** which changes the shape of the pattern **1**a of the mold **1** includes the adjusting unit **30** (actuator) which adjusts at least one of the angle and position of the contact member **26** which comes into contact with the side surface of the mold **1**. With this arrangement, the contact surface **26**c of the contact member **26** can be set parallel to the side surface of the mold **1**, and the center of the contact surface **26**c can be set at the neutral position of the mold **1**. Therefore, in performing magnification correction of the pattern **1**a by applying a force to the side surface of the mold **1**, distortion of the mold **1** can be suppressed to reduce stress concentration that may occur locally in the pattern **1**a of the mold **1**, and, in turn, to overlay the mold **1** on the substrate **2** with high accuracy. Also, since the adjusting unit **30** (actuators **30**a and **30**b) can be built into the changing unit **24**, the space to place an adjusting unit can be saved to increase the number of changing units **24**.

Note that as a modification to the above-mentioned embodiment, the distal end of the contact member **26** may be formed in a convex shape (for example, a mountain or spherical shape). FIG. **12** is a view illustrating an example in which the resin member **26**a at the distal end of the contact member **26** is formed in a mountain shape. The resin member **26**a has a ridgeline at the position where two flat surfaces intersect with each other. The ridgeline desirably

falls within the range of 250 μm from the neutral position of the mold **1**. Also, as shown in FIG. **12**, the angle θ1 that the Y-Z plane (a plane perpendicular to the pattern portion) makes with the side surface of the mold **1**, and the angle θ2 that the Y-Z plane makes with the distal end of the contact member **26** desirably satisfy θ1<θ2. The angle θ2 and the material of the resin member **26***a* can be appropriately set in consideration of a reduction in stress concentration, and the stroke of a magnification correction mechanism.

With this arrangement, the distal end of the contact member **26** is formed in a convex shape to make it easy to bring the contact member **26** into contact with the portion at the neutral position of the mold **1**. Also, in terms of a reduction in stress concentration, the distal end of the contact member **26** desirably has a flat surface insofar as the distal end of the contact member **26** is expected to come into contact with the portion at the neutral position of the mold **1**.

Second Embodiment

An imprint apparatus according to the second embodiment of the present invention will be described with reference to FIG. **9**. FIG. **9** is a sectional view showing a cross-section of a mold **1** and a changing unit **24** in the second embodiment. The imprint apparatus according to the second embodiment is different from the imprint apparatus **100** according to the first embodiment in the configuration of an adjusting unit **30**, and in the former the adjusting unit **30** includes an actuator **30***c* and converting unit **30***d*. The actuator **30***c* applies a force in a direction (X-direction) opposite to that (first direction) in which a contact member **26** presses the mold **1** from its side surface. The converting unit **30***d* includes an inclined part **30***e*, and moves in the X-direction upon receiving a force generated by the actuator **30***c*. An inclined plane **25***a* is formed on a base unit **25** to be in contact with the inclined part **30***e* of the converting unit **30***d*, and have an angle of inclination corresponding to the inclined part **30***e*. As the converting unit **30***d* moves in the X-direction, a force in the first direction is converted into that in the second direction by the inclined part **30***e* of the converting unit **30***d*, and the inclined plane **25***a* of the base unit **25**, so a member **29***a* can move in the −Z-direction. With this operation, the angle ωy of the contact member **26** can be adjusted, and a contact surface **26***c* of the contact member **26** can be set parallel to the side surface of the mold **1**. Therefore, as in the imprint apparatus **100** according to the first embodiment, in performing magnification correction of a pattern **1***a* by applying a force to the side surface of the mold **1**, distortion of the mold **1** can be suppressed, thus overlaying the mold **1** on a substrate **2** with high accuracy. Also, the imprint apparatus according to the second embodiment is effective when the angle of the contact member **26** is adjusted by increasing its resolution, using an actuator which produces a relatively small force and has a large stroke. Although the actuator **30***c* in the second embodiment applies a force in the X-direction, it may apply a force in the −X-direction.

Third Embodiment

An imprint apparatus according to the third embodiment of the present invention will be described with reference to FIG. **10**. FIG. **10** is a sectional view showing a cross-section of a mold **1** and a changing unit **24** in the third embodiment. The imprint apparatus according to the third embodiment is different from the imprint apparatus **100** according to the first embodiment in the configuration of an adjusting unit **30**, and in the former the adjusting unit **30** includes an actuator **30***f*. Also, a cut portion **25***b* is formed in a base unit **25** by cutting in the X-direction, so a portion **25***c* which supports a member **29***a* on the base unit **25** is formed thin by the cut portion **25***b*. The portion **25***c* of the base unit **25** is provided with the actuator **30***f*, and the member **29***a* can be moved in the −Z-direction by changing the width of the cut portion **25***b* by the actuator **30***f*. With this operation, an angle ωy of a contact member **26** can be adjusted, and a contact surface **26***c* of the contact member **26** can be set parallel to the side surface of the mold **1**. Therefore, as in the imprint apparatus **100** according to the first embodiment, in performing magnification correction of a pattern **1***a* by applying a force to the side surface of the mold **1**, distortion of the mold **1** can be suppressed, thus overlaying the mold **1** on a substrate **2** with high accuracy. Also, the imprint apparatus according to the third embodiment is effective when an actuator cannot be disposed on the member **29***a* because of an insufficient space. Note that in the third embodiment, adjustment may be manually done using a bolt in place of the actuator **30***f*. In this case, there is no need to use an actuator, so a simple, low-cost arrangement can be used. This arrangement is effective when the differences in shape between individual molds **1** are small, and only initial assembly and adjustment are performed.

Fourth Embodiment

An imprint apparatus according to the fourth embodiment of the present invention will be described with reference to FIG. **11**. FIG. **11** is a sectional view showing a cross-section of a mold **1** and a changing unit **24** in the fourth embodiment. The imprint apparatus according to the fourth embodiment is different from the imprint apparatus **100** according to the first embodiment in the configuration of an adjusting unit **30**, and in the former the adjusting unit **30** includes actuators **30***g* and **30***h*. The actuator **30***g* is disposed in the middle of a member **29***a*, and can change the distance between a base unit **25** and a contact member **26** upon driving it. This amounts to changing the length of the member **29***a*. Similarly, the actuator **30***h* is disposed in the middle of a member **29***b*, and can change the distance between the base unit **25** and the contact member **26** upon driving it. With this operation, an angle ωy of the contact member **26** can be adjusted, a contact surface **26***c* of the contact member **26** can be set parallel to the side surface of the mold **1**, and the center of the contact surface **26***c* can be set at a neutral position **1***d* of the mold **1**. Therefore, as in the imprint apparatus **100** according to the first embodiment, in performing magnification correction of a pattern **1***a* by applying a force to the side surface of the mold **1**, distortion of the mold **1** can be suppressed, thus overlaying the mold **1** on a substrate **2** with high accuracy. Also, the imprint apparatus according to the fourth embodiment is effective when the space to place an actuator is narrow, members cannot reliably have sufficient lengths, and a link mechanism can hardly be formed.

<Embodiment of Method of Manufacturing Article>

A method of manufacturing an article according to an embodiment of the present invention is suitable for manufacturing various articles including a microdevice such as a semiconductor device and an element having a microstructure. The method of manufacturing an article according to this embodiment includes a step of forming a pattern on a resin, dispensed on a substrate, using the above-mentioned imprint apparatus (a step of performing an imprint process

on a substrate), and a step of processing the substrate having the pattern formed on it in the forming step. This manufacturing method also includes subsequent known steps (for example, oxidation, film formation, vapor deposition, doping, planarization, etching, resist removal, dicing, bonding, and packaging). The method of manufacturing an article according to this embodiment is more advantageous in terms of at least one of the performance, quality, productivity, and manufacturing cost of an article than the conventional method.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application Nos. 2012-107035, filed on May 8, 2012 and 2013-078096, filed Apr. 3, 2013, which are hereby incorporated by reference herein in their entirety.

What is claimed is:

1. An imprint apparatus which forms a pattern to an imprint material on a substrate using a mold, the apparatus comprising:

a changing unit which includes a contact member having a contact surface that comes into contact with a side surface of the mold, and is configured to apply a force to the side surface of the mold through the contact member to change a shape of the mold; and

an adjusting unit configured to adjust an angle of the contact member to change a relative angle between the contact surface and the side surface of the mold.

2. The apparatus according to claim **1**, wherein

the contact member is supported through a plurality of members by a base unit fixed to a holding unit configured to hold the mold, and

the plurality of members form a link mechanism which allows the contact member to move in a first direction in which the contact member presses the mold.

3. The apparatus according to claim **2**, wherein the adjusting unit is disposed on the base unit, and drives at least one of the plurality of members in a second direction different from the first direction.

4. The apparatus according to claim **3**, wherein the adjusting unit includes an actuator configured to drive at least one of the plurality of members in the second direction.

5. The apparatus according to claim **3**, wherein

the adjusting unit includes a converting unit including an inclined part, and an actuator configured to apply a force in the first direction to the converting unit,

the base unit includes an inclined plane in contact with the inclined part, and

the converting unit converts the force in the first direction into a force in the second direction using the inclined part and the inclined plane to drive at least one of the plurality of members in the second direction.

6. The apparatus according to claim **2**, wherein

the adjusting unit includes an actuator disposed on at least one of the plurality of members, and

the actuator is disposed on at least one of the plurality of members to be capable of changing a distance between the base unit and the contact member.

7. The apparatus according to claim **1**, wherein

the adjusting unit adjusts the angle of the contact member based on shape information of the mold, and

the shape information includes a tilt of the side surface of the mold.

8. The apparatus according to claim **1**, further comprising:

a measurement unit configured to measure a position deviation between an alignment mark formed on the mold, and an alignment mark formed on the substrate,

wherein the adjusting unit adjusts the angle of the contact member to reduce the position deviation measured by the measurement unit.

9. The apparatus according to claim **1**, further comprising:

a measurement unit configured to measure a deformation amount in which an outer peripheral region of the mold deforms in a direction, different from the direction in which the mold is pressed, upon applying a force to the side surface of the mold by the changing unit,

wherein the outer peripheral region includes a region that falls outside a portion held by a holding unit in the mold, and

the adjusting unit adjusts the angle of the contact member to reduce the deformation amount measured by the measurement unit.

10. The apparatus according to claim **1**, wherein a distal end of the contact member has a convex shape.

11. The apparatus according to claim **1**, wherein the adjusting unit adjusts the angle of the contact member such that the contact surface and the side surface of the mold are in parallel to each other.

12. The apparatus according to claim **1**, wherein the adjusting unit moves the contact member in a direction in which the contact member presses the mold, while maintaining the angle of the contact member.

13. The apparatus according to claim **1**, wherein

the contact member is supported through a plurality of members by a base unit fixed to a holding unit configured to hold the mold, and

the adjusting unit adjusts the angle of the contact member by individually driving the plurality of members in a direction in which the mold presses the imprint material.

14. The apparatus according to claim **1**, wherein the adjusting unit further adjusts a position of the contact member.

15. The apparatus according to claim **1**, wherein the adjusting unit further adjusts a position of the contact member in a direction in which the mold presses the imprint material.

16. An imprint apparatus which forms a pattern to an imprint material on a substrate using a mold, the apparatus comprising:

a changing unit which includes a contact member having a contact surface that comes into contact with a side surface of the mold, and is configured to apply a force to the side surface of the mold through the contact member to change a shape of the mold; and

an adjusting unit configured to adjust a position of the contact member in a direction in which the mold presses the imprint material to change a relative position between the contact member and the side surface of the mold.

17. The apparatus according to claim **16**, wherein

the contact member is supported through a plurality of members by a base unit fixed to a holding unit configured to hold the mold, and

the plurality of members form a link mechanism which allows the contact member to move in the direction in which the contact member presses the mold.

18. The apparatus according to claim **17**, wherein the adjusting unit is disposed on the base unit, and drives at least one of the plurality of members in a second direction different from the direction.

19. The apparatus according to claim **18**, wherein the adjusting unit includes an actuator configured to drive at least one of the plurality of members in the second direction.

20. The apparatus according to claim **18**, wherein

the adjusting unit includes a converting unit including an inclined part, and an actuator configured to apply a force in the direction to the converting unit,

the base unit includes an inclined plane in contact with the inclined part, and

the converting unit converts the force in the direction into a force in the second direction using the inclined part and the inclined plane to drive at least one of the plurality of members in the second direction.

21. The apparatus according to claim **17**, wherein

the adjusting unit includes an actuator disposed on at least one of the plurality of members, and

the actuator is disposed on at least one of the plurality of members to be capable of changing a distance between the base unit and the contact member.

22. The apparatus according to claim **16**, wherein

the adjusting unit adjusts the position of the contact member based on shape information of the mold, and

the shape information includes a thickness of the mold.

23. The apparatus according to claim **16**, further comprising:

a measurement unit configured to measure a position deviation between an alignment mark formed on the mold, and an alignment mark formed on the substrate,

wherein the adjusting unit adjusts the contact member to reduce the position deviation measured by the measurement unit.

24. The apparatus according to claim **16**, further comprising:

a measurement unit configured to measure a deformation amount in which an outer peripheral region of the mold deforms in a direction, different from the direction in which the mold is pressed, upon applying a force to the side surface of the mold by the changing unit,

wherein the outer peripheral region includes a region that falls outside a portion held by a holding unit in the mold, and

the adjusting unit adjusts the contact member to reduce the deformation amount measured by the measurement unit.

25. The apparatus according to claim **16**, wherein a distal end of the contact member has a convex shape.

26. The apparatus according to claim **16**, wherein the adjusting unit adjusts the position of the contact member such that a center of the contact surface is set at a neutral position of the mold.

27. The apparatus according to claim **16**, wherein

the contact member is supported through a plurality of members by a base unit fixed to a holding unit configured to hold the mold, and

the adjusting unit adjusts the position of the contact member by driving, in a same amount, the plurality of members in the direction.

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